Edexcel A2 Physics: Nuclear Radiation – Calculation Practice

Praneel Physics

1. A radioactive isotope has a half-life of 5 years. If you start with 80 g of the isotope, how much will remain after 15 years? **(P)**

Working and Answer:

After 15 years, the number of half-lives is $n = \frac{15}{5} = 3$. Remaining mass $= 80 \times \left(\frac{1}{2}\right)^3 = 80 \times \frac{1}{8} = 10$ g.

2. A sample contains 2000 radioactive nuclei. If the decay constant is $0.693\,\text{year}^{-1}$, how long will it take for the sample to decay to 1000 nuclei? **(P)**

Working and Answer:
Using the formula $N = N_0 e^{-\lambda t}$, we have $1000 = 2000e^{-0.693t}$. Thus, $e^{-0.693t} = \frac{1}{2}$. Taking natural log: $-0.693t = \ln\left(\frac{1}{2}\right) \Rightarrow t = 1$ year.

3. If a radioactive source emits 5 counts per second at a distance of 2 m, what will be the count rate at a distance of 4 m? **(P)**

Working and Answer:
Using the inverse square law: $I \propto \frac{1}{r^2}$. Thus, $\frac{I_2}{I_1} = \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{2}{4}\right)^2 = \frac{1}{4}$. Therefore, $I_2 = 5 \times \frac{1}{4} = 1.25$ counts per second.

4. A Geiger counter detects 120 counts in 2 minutes. What is the count rate in counts per second? **(P)**

Working and Answer:
Count rate $= \frac{120 \text{ counts}}{120 \text{ seconds}} = 1$ count per second.

5. A radioactive material has a half-life of 10 days. If you have 160 g of it, how much will remain after 30 days? **(P)**

Working and Answer:
Number of half-lives $n = \frac{30}{10} = 3$. Remaining mass $= 160 \times \left(\frac{1}{2}\right)^3 = 160 \times \frac{1}{8} =$ 20 g.

6. A sample of a radioactive isotope has a decay constant of $0.1\,\text{day}^{-1}$. How long will it take for the sample to reduce to 25% of its original amount? **(PP)**

Working and Answer:
Using $N = N_0 e^{-\lambda t}$, we set $N = 0.25N_0$. Thus, $0.25 = e^{-0.1t}$. Taking natural log: $\ln(0.25) = -0.1t \Rightarrow t = \frac{\ln(0.25)}{-0.1} \approx 13.86$ days.

7. If a radioactive source has a decay constant of $0.693\,\text{year}^{-1}$, what is its half-life? **(PP)**

Working and Answer:
Half-life $T_{1/2} = \frac{\ln(2)}{\lambda} = \frac{0.693}{0.693} = 1$ year.

8. A radioactive isotope has a half-life of 3 hours. If you start with 64 g, how much will remain after 9 hours? **(PP)**

Working and Answer:
Number of half-lives $n = \frac{9}{3} = 3$. Remaining mass $= 64 \times \left(\frac{1}{2}\right)^3 = 64 \times \frac{1}{8} = 8$ g.

9. A sample contains 800 radioactive nuclei. If the decay constant is $0.346\,\text{day}^{-1}$, how long will it take for the sample to decay to 200 nuclei? **(PP)**

Working and Answer: Using $N = N_0 e^{-\lambda t}$, we have $200 = 800e^{-0.346t}$. Thus, $e^{-0.346t} = \frac{1}{4}$. Taking natural log: $-0.346t = \ln\left(\frac{1}{4}\right) \Rightarrow t \approx 10.06$ days.

10. A radioactive source emits 10 counts per second at a distance of 1 m. What will be the count rate at a distance of 3 m? **(PP)**

Working and Answer: Using the inverse square law: $I_2 = I_1 \left(\frac{r_1}{r_2}\right)^2 = 10\left(\frac{1}{3}\right)^2 = 10 \times \frac{1}{9} \approx$ 1.11 counts per second.

11. A radioactive isotope has a half-life of 2 years. If you have 32 g of it, how much will remain after 6 years? **(PPP)**

Working and Answer:
Number of half-lives $n = \frac{6}{2} = 3$. Remaining mass $= 32 \times \left(\frac{1}{2}\right)^3 = 32 \times \frac{1}{8} = 4$ g.

12. A sample of a radioactive isotope has a decay constant of $0.2\,\text{year}^{-1}$. How long will it take for the sample to reduce to 12.5% of its original amount? **(PPP)**

Working and Answer:
Using $N = N_0 e^{-\lambda t}$, we set $N = 0.125 N_0$. Thus, $0.125 = e^{-0.2t}$. Taking natural log: $\ln(0.125) = -0.2t \Rightarrow t = \frac{\ln(0.125)}{-0.2} \approx 8.05$ years.

13. A radioactive source has a decay constant of $0.693\,\text{day}^{-1}$. What is the half-life of the source? **(PPP)**

Working and Answer:
Half-life $T_{1/2} = \dfrac{\ln(2)}{\lambda} = \dfrac{0.693}{0.693} = 1$ day.

14. A sample contains 1000 radioactive nuclei. If the decay constant is $0.1\,\text{day}^{-1}$, how long will it take for the sample to decay to 500 nuclei? **(PPP)**

Working and Answer:
Using $N = N_0 e^{-\lambda t}$, we have $500 = 1000e^{-0.1t}$. Thus, $e^{-0.1t} = \dfrac{1}{2}$. Taking natural log: $-0.1t = \ln\left(\dfrac{1}{2}\right) \Rightarrow t = 6.93$ days.

15. A radioactive isotope has a half-life of 4 hours. If you start with 128 g, how much will remain after 12 hours? **(PPP)**

Working and Answer:
Number of half-lives $n = \frac{12}{4} = 3$. Remaining mass $= 128 \times \left(\frac{1}{2}\right)^3 = 128 \times \frac{1}{8} =$ 16 g.

16. A radioactive source emits 20 counts per second at a distance of 2 m. What will be the count rate at a distance of 5 m? **(PPP)**

Working and Answer:
Using the inverse square law: $I_2 = I_1 \left(\frac{r_1}{r_2}\right)^2 = 20\left(\frac{2}{5}\right)^2 = 20 \times \frac{4}{25} =$ 3.2 counts per second.

17. A radioactive isotope has a half-life of 6 days. If you have 96 g of it, how much will remain after 18 days? **(PPPP)**

Working and Answer:
Number of half-lives $n = \frac{18}{6} = 3$. Remaining mass $= 96 \times \left(\frac{1}{2}\right)^3 = 96 \times \frac{1}{8} =$ 12 g.

18. A sample of a radioactive isotope has a decay constant of $0.5\,\text{year}^{-1}$. How long will it take for the sample to reduce to 25% of its original amount? **(PPPP)**

Working and Answer:
Using $N = N_0 e^{-\lambda t}$, we set $N = 0.25 N_0$. Thus, $0.25 = e^{-0.5t}$. Taking natural log: $\ln(0.25) = -0.5t \Rightarrow t = \frac{\ln(0.25)}{-0.5} \approx 5.54$ years.

19. A radioactive source has a decay constant of 0.693 year^{-1}. What is the half-life of the source? **(PPPP)**

Working and Answer:
Half-life $T_{1/2} = \dfrac{\ln(2)}{\lambda} = \dfrac{0.693}{0.693} = 1$ year.

20. A sample contains 2000 radioactive nuclei. If the decay constant is 0.346 day^{-1}, how long will it take for the sample to decay to 500 nuclei? **(PPPP)**

Working and Answer:
Using $N = N_0 e^{-\lambda t}$, we have $500 = 2000e^{-0.346t}$. Thus, $e^{-0.346t} = \dfrac{1}{4}$. Taking natural log: $-0.346t = \ln\left(\dfrac{1}{4}\right) \Rightarrow t \approx 10.06$ days.

21. A radioactive isotope has a half-life of 5 years. If you start with 160 g, how much will remain after 15 years? **(PPPP)**

Working and Answer: Number of half-lives $n = \frac{15}{5} = 3$. Remaining mass $= 160 \times \left(\frac{1}{2}\right)^3 = 160 \times \frac{1}{8} =$ 20 g.

22. A radioactive source emits 15 counts per second at a distance of 1 m. What will be the count rate at a distance of 4 m? **(PPPP)**

Working and Answer: Using the inverse square law: $I_2 = I_1 \left(\frac{r_1}{r_2}\right)^2 = 15 \left(\frac{1}{4}\right)^2 = 15 \times \frac{1}{16} =$ 0.9375 counts per second.

23. A radioactive isotope has a half-life of 8 days. If you have 256 g of it, how much will remain after 24 days? **(PPPPP)**

Working and Answer:
Number of half-lives $n = \frac{24}{8} = 3$. Remaining mass $= 256 \times \left(\frac{1}{2}\right)^3 = 256 \times \frac{1}{8} =$ 32 g.

24. A sample of a radioactive isotope has a decay constant of $0.1\,\text{year}^{-1}$. How long will it take for the sample to reduce to 12.5% of its original amount? **(PPPPP)**

Working and Answer:
Using $N = N_0 e^{-\lambda t}$, we set $N = 0.125N_0$. Thus, $0.125 = e^{-0.1t}$. Taking natural log: $\ln(0.125) = -0.1t \Rightarrow t = \frac{\ln(0.125)}{-0.1} \approx 20.79$ years.

25. A radioactive source has a decay constant of $0.346\,\text{day}^{-1}$. What is the half-life of the source? **(PPPPP)**

Working and Answer:
Half-life $T_{1/2} = \dfrac{\ln(2)}{\lambda} = \dfrac{0.693}{0.346} \approx 2$ days.

26. A sample contains 4000 radioactive nuclei. If the decay constant is $0.693\,\text{year}^{-1}$, how long will it take for the sample to decay to 1000 nuclei? **(PPPPP)**

Working and Answer:
Using $N = N_0 e^{-\lambda t}$, we have $1000 = 4000e^{-0.693t}$. Thus, $e^{-0.693t} = \dfrac{1}{4}$. Taking natural log: $-0.693t = \ln\left(\dfrac{1}{4}\right) \Rightarrow t \approx 4.16$ years.

27. A radioactive isotope has a half-life of 10 days. If you start with 128 g, how much will remain after 30 days? **(PPPPP)**

Working and Answer:
Number of half-lives $n = \frac{30}{10} = 3$. Remaining mass $= 128 \times \left(\frac{1}{2}\right)^3 = 128 \times \frac{1}{8} = 16$ g.